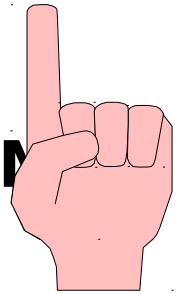
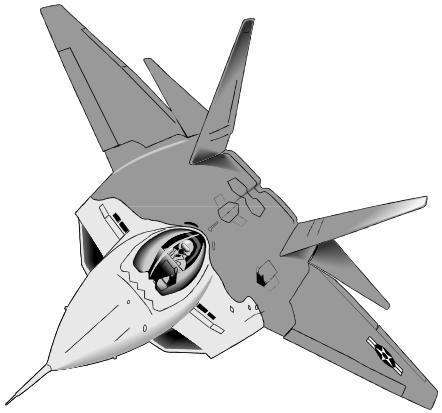
LM-720
Reliability, Availability, & Maintainability (RAM)
(Hardware and Software)



Given a scenario, examine the process and impacts of Reliability, Availability, and Maintainability policies and program objectives on systems design and performance for both hardware and software.

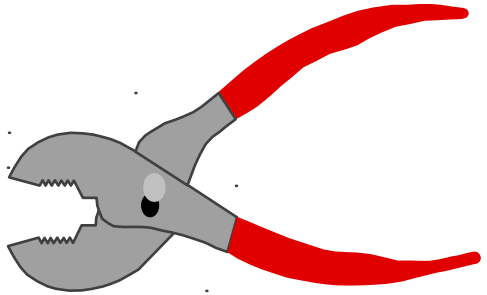
- **Discuss DoD policies and management methods to achieve Reliability, Availability and Maintainability goals.**
- **Compare and contrast the effectiveness of various Reliability, Availability, and Maintainability techniques.**
- **Analyze the effects of Reliability, Availability, and Maintainability on operational effectiveness and life cycle costs.**

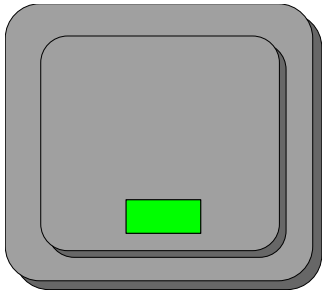
INFORMAL RAM DEFINITIONS
What are your definitions?



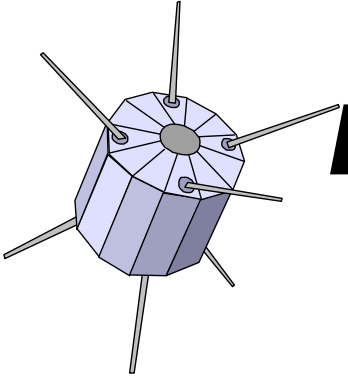
RELIABILITY?

AVAILABILITY?





MAINTAINABILITY?



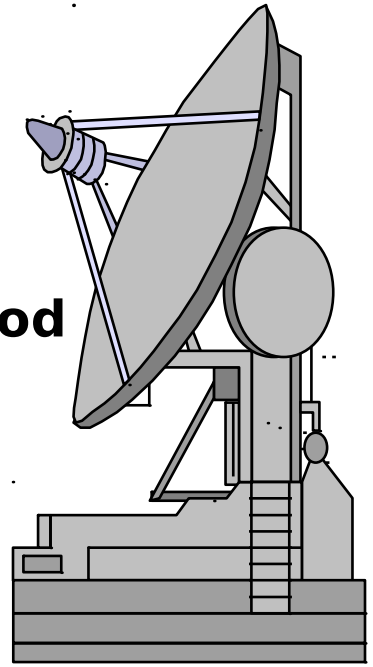
FORMAL RAM DEFINITIONS

(ASQC RAM dictionary)

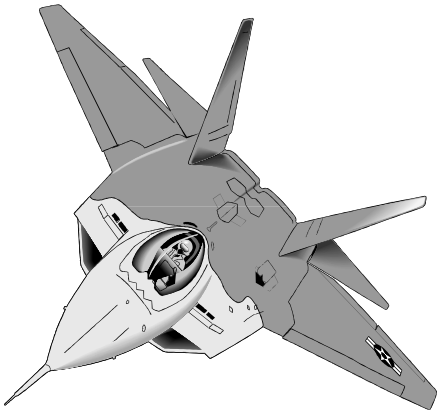
RELIABILITY: **The probability an item will perform its intended functions for a specified period under stated conditions.**

AVAILABILITY: **A measure of the degree to which an item is in the operable and committable state at the start of a mission when the mission is called for an unknown (random) time.**

MAINTAINABILITY: **The probability an item will conform to specified conditions within a given period when corrective or preventive action is performed IAW prescribed procedures and resources.**



AVAILABILITY



$$A_I = \frac{MTBF}{MTBF + MTTR}$$

$$A_A = \frac{MTBM}{MTBM + MMT}$$

$$A_o = \frac{MTBM}{MTBM + MMT + MLDT}$$

$$LDT + ADT$$

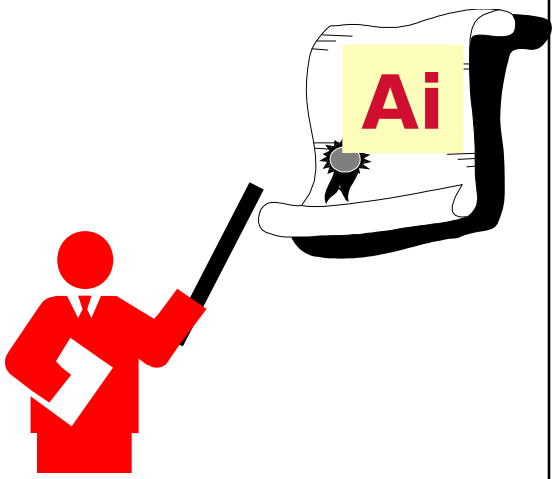
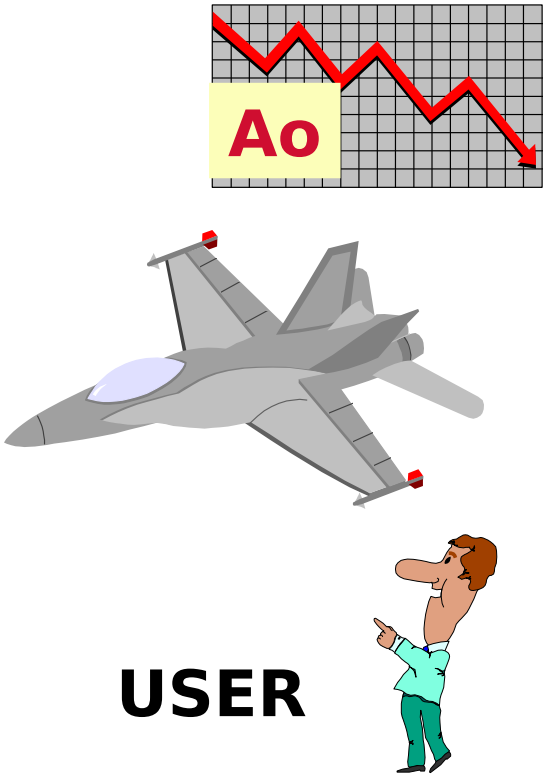
A_I - Inherent Availability
A_A - Achieved Availability
A_o - Operational Availability

MTBF - Mean Time Between Failure
MTTR - Mean Time to Repair
MLDT - Mean Logistics Down Time
MTBM - Mean Time Between Maintena
MMT - Mean Maintenance Time

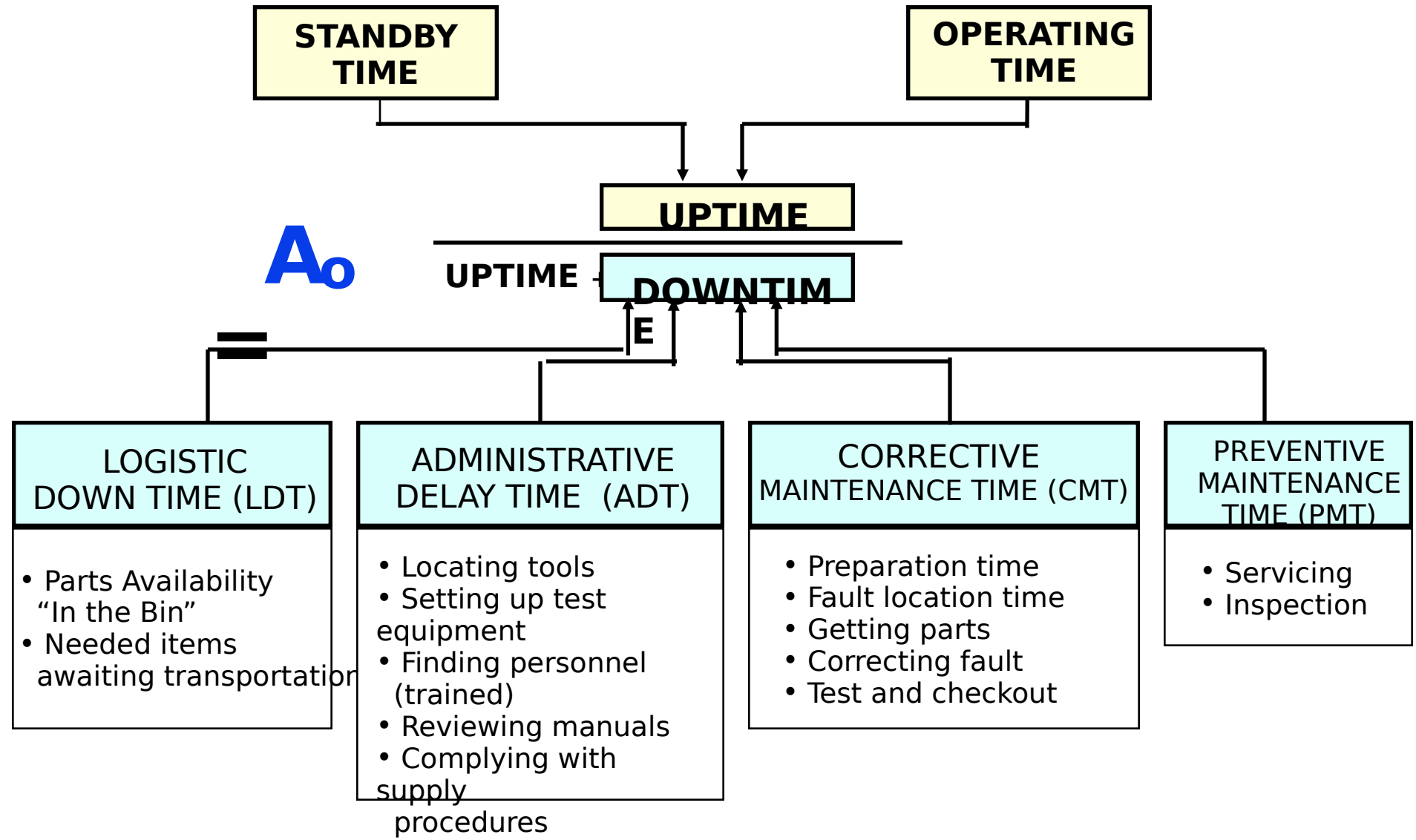
LDT - Logistics Delay Time
ADT - Administrative Delay Time

KNOW YOUR TERMS ?

- Ensure your IPT members all use the same termi

CONTRACTOR	DESIGNER	USER
CONTRACT Ai 	Aa 	Ao 

OPERATIONAL AVAILABILITY



Factors comprising A_o

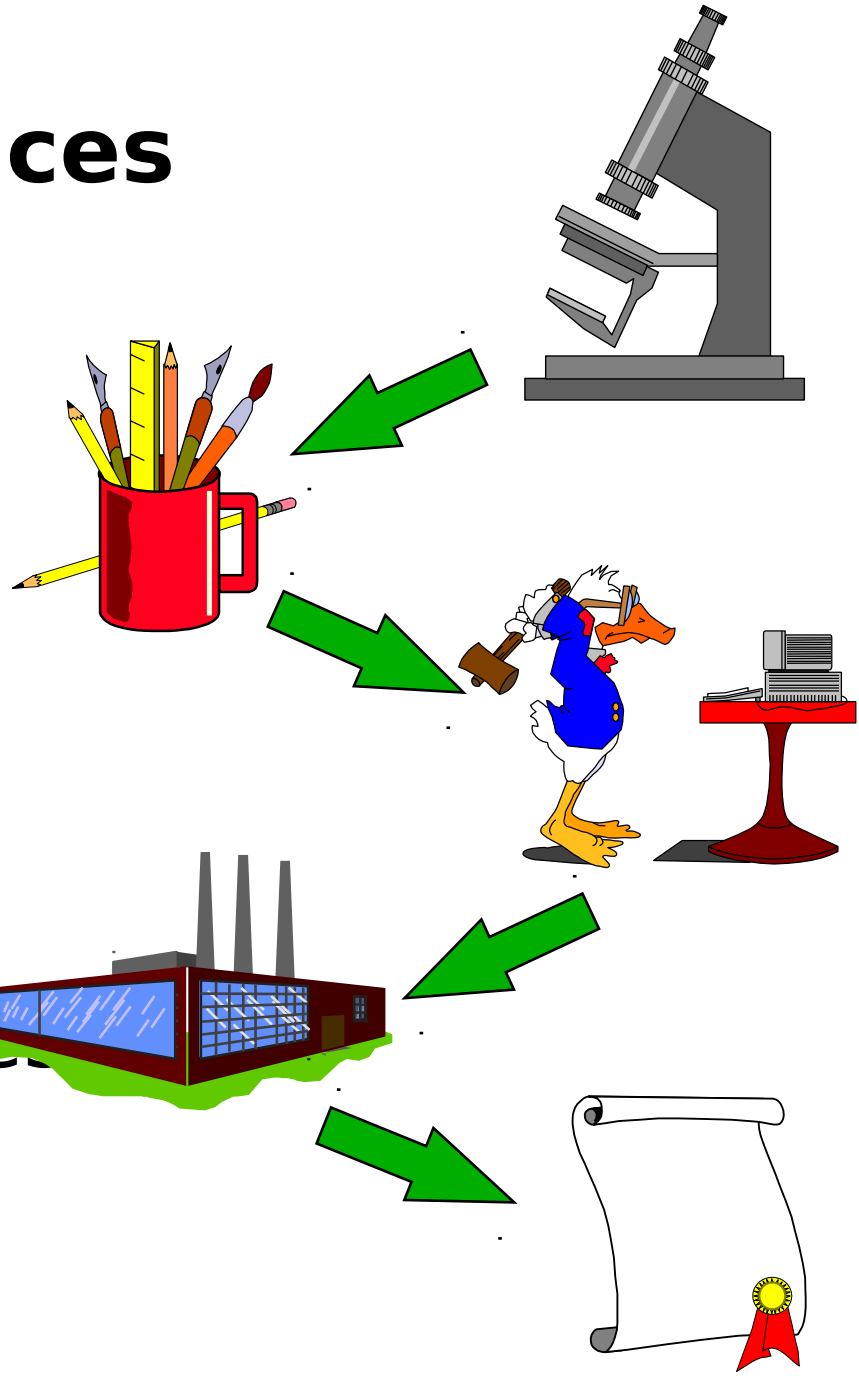
RAM POLICY

- PM establishes RAM activities to meet operational needs and reduce life-cycle costs.
- RAM requirements stated in quantifiable terms.
- Reliability requirements shall address:
  - Both mission and logistics reliability
- Maintainability requirements shall address:
  - Servicing
  - Preventive and corrective maintenance
- Availability requirements shall address:
  - Readiness of the system

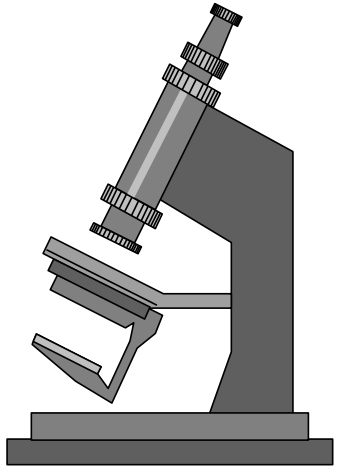
DoD 5000.2-R

RAM
Best Practices

- Analyze
- Design
- Test
- Reliability Production & In-Service Techniques
- Contract

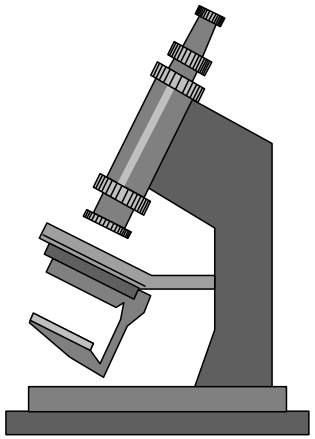


RAM ANALYSES: Techniques



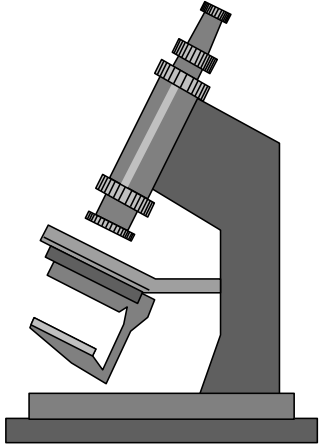
- **Reliability Prediction Methods**
- **Failure Mode, Effects and Criticality Analysis (FMECA)**
- **Reliability Centered Maintenance (RCM) Analysis**
- **Level of Repair Analysis(LORA)**

RAM ANALYSES: Reliability Prediction Methods



- **Developmental Methods**
  - **Allocation**
  - **Handbooks** ***Supportability***
  - **Comparative** ***Analyses***
  - **Testing** ***Inputs***
- **Problems**
  - **Field Tests Results do not match predictions**
- **Commercial/NDI - Are the data environments similar?**

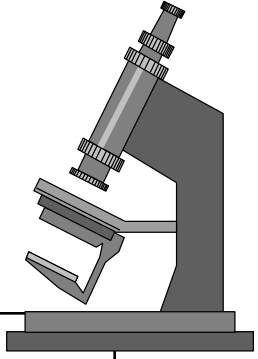
RAM ANALYSES: Failure Modes, Effects and Criticality Analysis (FMECA)



- **DEFINITION:**
  - **A review that examines potential failure modes to determine their effects on equipment.**
  - **Employs a "bottoms-up" approach.**

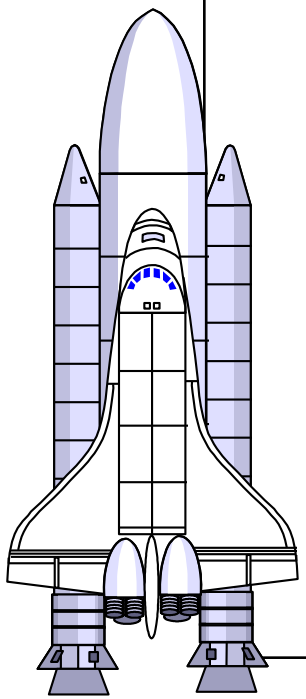
- **USES:**
  - **Identifies areas needing corrective action**
  - **Ranks severity of failures/safety issues**
  - **Identifies reliability-critical components**
  - **Inputs to systems engineering and logistics**

FAILURE MODES, EFFECTS AND CRITICALITY ANALYSIS (FMECA)

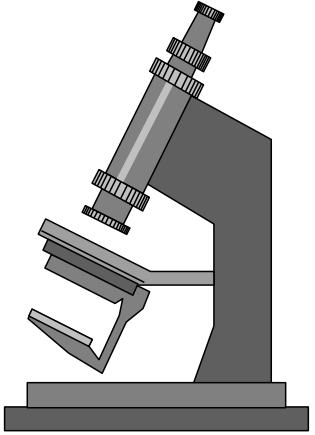


SYSTEM NAME	SUBSYSTEM NAME	COMPONENT NAME AND PART NO.	COMPONENT FUNCTION
SPACE SHUTTLE MP SRM 10-00	SRM CASE 10-06	CASE ASSEMBLY, FORWARD SEGMENT 10-05-01 1U50147-08	Example
AUTHOR AND COMPANY W. L. HANKINE THIOKOL CORPORATION	**DATE** JUNE 1983	**REVISION**	

MISSION PHASE	COMPONENT FAILURE MODE AFFECTED COMPONENT	FAILURE EFFECT ON A. SUBSYSTEM FUNCTION B. SYSTEM FUNCTION C. MISSION D. VEHICLE AND PERSONNEL	CRITICALITY CATEGORY	CONTROL METHODS TO INSURE A RELIABLE PRODUCT
	ASSEMBLY JOINTS LEAK.	A. HIGH TEMPERATURE GAS FLOW WILL CAUSE METAL EROSION AND PROBABLE BURNTHROUGH AND CASE BURST. B. CATASTROPHIC FAILURE OF SRM. C. MISSION LOSS. D. ***VEHICLE AND PERSONNEL LOSS.***	1	SEE CIL
	PART NO. / PART NAME / QUANTITY PER COMPONENT 1U50131-09 CASE SEGMENT, CYLINDER 2 1U51473-01 CASE SEGMENT, FORWARD 1 1U50228-24 PACKING (O-RINGS) 2/JOINT 1U100269-01 TEST PLUG 1/JOINT 1U50228-15 PACKING (TEST PLUG) 1/PLUG			
	1. TANG-A-DIAMETER EXCEEDS UPPER LIMIT OR SURFACE FINISH NONCONFORMING, OR IS GOUGEDRFACES.		(1)	1. TRAINED, QUALIFIED MACHINIST TO PERFORM MACHINING OPERATION.
	2. CLEVIS NONCONFORMING (DIAMETER, THICKNESS, FINISH).		(1R)	2. SPECIAL PROFILE TEMPLATE TO CONTROL LATHE CUTTING HEAD.
	3. CLEVIS O-RING GROOVES EXCEED WIDTH AND/OR DEPTH UPPER LIMITS OR CORRODED.		(1R)	3. 100% INSPECTION OF TANG-DIAMETER, CLEVIS, DIMEN - SIONS AND O-RING GROOVES USING PI TAPE AND STAND-DARD MEASURING INSTRU-MENTS . SURFACE FINISH SAMPLE INSPECTED BY SURF-INDICATOR.
	4. 0-RINGS NONCONFORMING OR DAMAGED DURING ASSEM-BLY.		(1R)	
	5. LEAK CHECK PLUG LOOSE OR WITHOUT O-RING, INNERMOST SEAL INEFFECTIVE PER 1 ABOVE OR THE CONDITIONS OF O-RING ARE PER 4 ABOVE.		(1)	
	6. ***FOREIGN MATERIAL IN O-RING GROOVES***.		(1R)	
	7. IGNITER FLANGE NONCONFORMING, FLATNESS FINISH.		(1R)	7. A. TRAINED, QUALIFIED MACHINIST TO PERFORM MACHINING OPERATION. B. 100% INSPECTION OF IGNITER FLANGE FLATNESS BY TIR READOUT FINISH IS SAMPLE INSPECTED USING SURF-INDICATOR.
	8. CASE ASSEMBLY JOINT ROTATION CAUSES “LIFT-OFF” FROM SECONDARY O-RING (PRIMARY O-RING WILL REMAIN IN COMPRESSION).		(1R)	
	9. EXPANSION OF CLEVIS GAP BECAUSE OF RESIDUAL STRAINS RESULTING FROM MANUFACTURING PROCESSES.		(1R)	



RAM ANALYSES: Reliability Centered Maintenance (RCM)



- **Definition: A methodology used to identify preventive maintenance tasks**
- **Goals of RCM**
  - **Increase operational readiness**
  - **Cost effective maintenance**
- **Products of RCM program**
  - **Inspections and time-related tasks**
- **Uses FMECA data in Maintenance Plan**

RCM Decision Questions

Identify specific functional failure the preventive maintenance task is designed to prevent

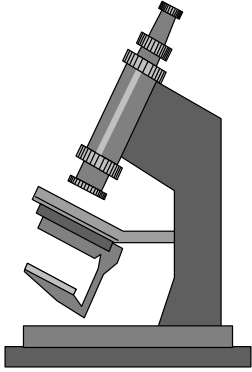
What is the consequence of that failure?

Direct adverse effect on operational capability?
Loss of function?
Cascading failure - secondary damage?
Safety consequences?

What does failure data & operating experience show?

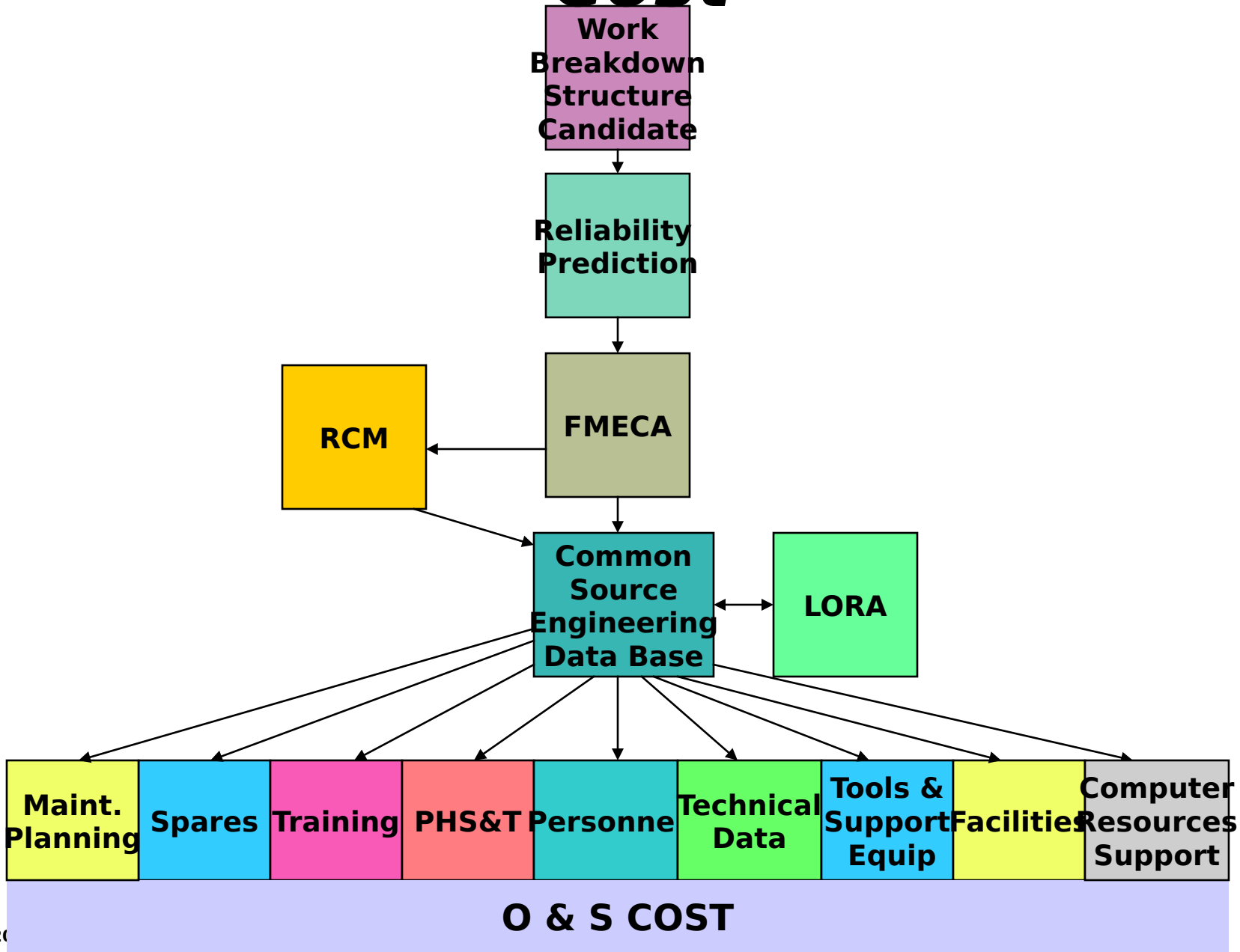
Cost - Does the task pay for itself?
Is cost less than the cost of repair & operation consequences?

RAM ANALYSES: Level of Repair Analyses (LORA)

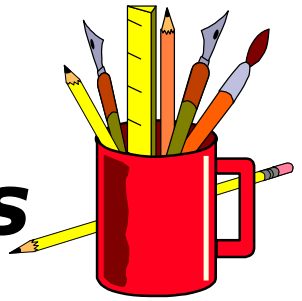


- **Evaluates maintenance actions to determine:**
  - **economic repair vs discarding an item**
  - **which maintenance level can the task be accomplished most effectively if repaired**

Using RAM Analyses To Lower O&S Cost



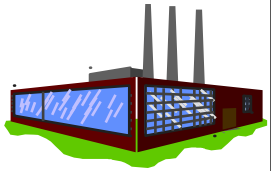
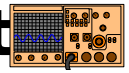
RAM DESIGN: Reliability Design Techniques



- **Mission profile**
- **Stress analysis**
- **Worst case analysis**
- **FMECA**
- **Sneak circuit**

- **Allocation**
- **Parts selection**
- **Derating criteria**
- **Simplification**
- **Design reviews**

RAM DESIGN: Maintainability Design Considerations

- Human engineering
- Accessibility
- Visibility
- Repair level 
- Test equipment 

- Tools
- Standardization
- Simplicity
- Skill requirements

SOFTWARE RAM

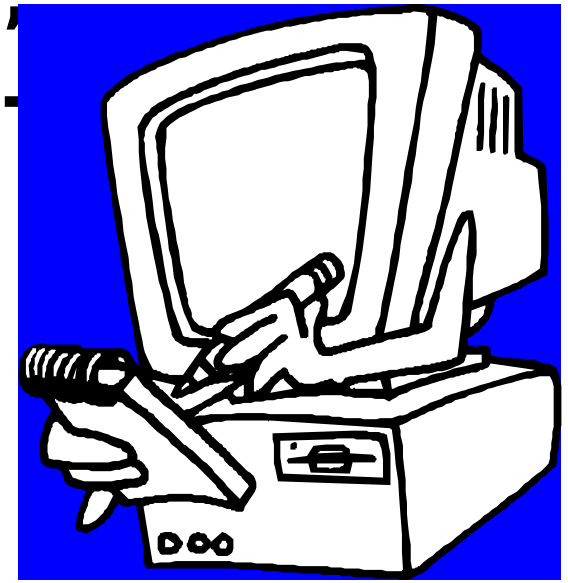
- **Common perception:**
  - **“THERE IS NO SUCH THING AS SOFTWARE RELIABILITY, BECAUSE SOFTWARE DOESN’T ‘FAIL’!”**

- **Parts fail during operation and prevent hardware from performing required functions.**

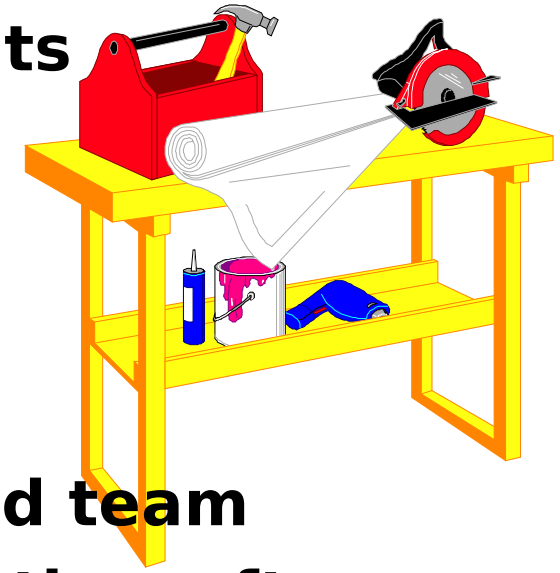
- **Software errors are incorporated during requirement, design & coding; may prevent hardware from performing required functions.**

CAUSES OF SOFTWARE ERRORS

"Forty percent of software errors result from incomplete or erroneous specifications (28%), or intentional deviations from the specifications (12%).' satellite program by T

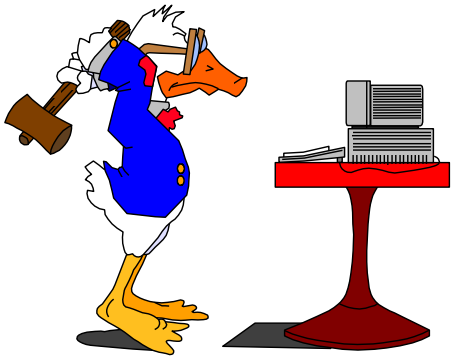


SOFTWARE RAM TOOLS



1. **Good identification of requirements**
2. **Modular design**
3. **Use of higher order languages**
4. **Use of a single language**
5. **Fault tolerance**
6. **Review and verification via second team**
7. **Functional testing - “debugging” the software**
8. **Good documentation will facilitate software maintenance.**

RAM TESTING: Policy

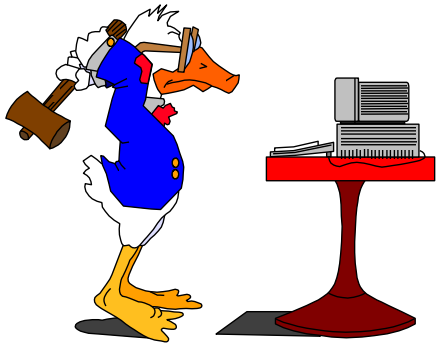


- **RAM shall be quantifiable in operational terms**
  - **Tested in DT and OT**
  - **Defined for all elements of the system (including training & support equipment)**

- **RAM Demonstration:**
  - **Production representative**

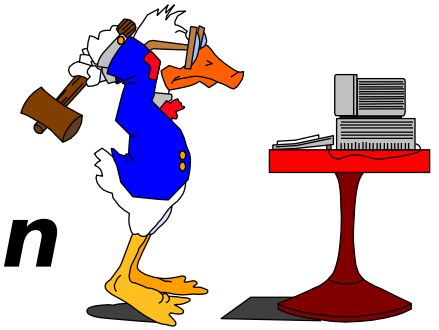
DoD 5000.2-R

RAM TESTING: Considerations



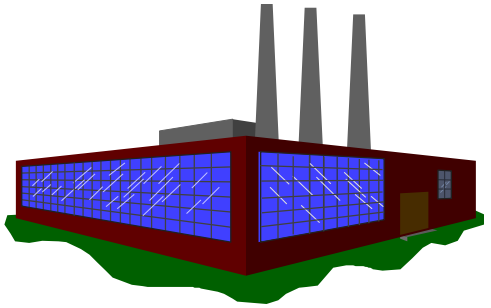
- **RAM included in TEMP**
- **Sufficient test schedule slack time**
- **Need a reporting and corrective action system**
- **Identify a realistic operational test scenario**
- **Field - onsite Contractor Engineering Team**
- **Logistics representative on T&E IPT**

RAM TESTING:
(EXAMPLE)
Maintainability Demonstration Test

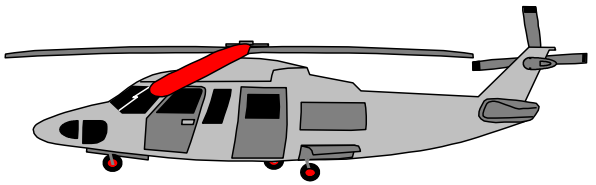


- **Formal "proof" of achieved maintainability**
- **Integrate with other testing requirements**
- **Strict adherence to ground rules and procedures**
- **Operational or simulated operational environment using appropriate maintenance**

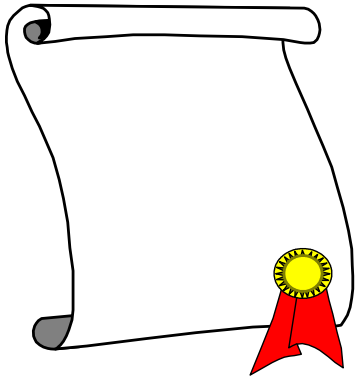
RELIABILITY PRODUCTION AND IN-SERVICE TECHNIQUES



- **Sustain reliability in production**
  - **Process control**
  - **Screening / acceptance tests**
  - **Burn-in**



- **Sustain reliability in service**
  - **Maintenance data collection systems**
  - **Analysis and corrective action**



RAM CONTRACTING

CE	PDRR	EMD	P, F/D, O&S
Encouraged through Incentives			Enforced through Warranties
Always a Source Selection / Evaluation Fac			

RAM CONTRACTING: Comanche Source Selection

SSEB WEIGHTING CRITERIA

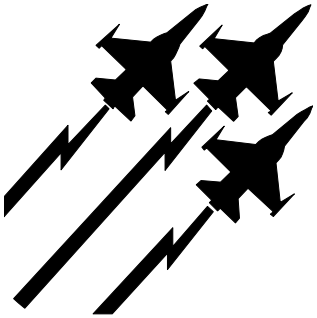
AREAS	COST 20%	TECHNICAL 35%	RAM/SUPPORT/ QUALITY 17.5%	MANPRINT/ TRAINING 17.5%	PRODUCIBILITY/ PRODUCTION COMPETITION 10%
ELEMENTS	DEVELOPMENT COST (10%)	AIR VEHICLE (40%)	RAM/ QUALITY (60%)	MANPRINT (50%)	PRODUCIBILITY (50%)
	DTC COMMITMENTS (40%)	MSN EQUIP PACKAGE (40%)	SUPPORTABILITY (40%)	TRAINING (50%)	PRODUCTION COMPETITION (50%)
	O & S COST COMMITMENTS (40%)	SOFTWARE (10%)	ORG/MGMNT/ PLANNING (GO/NO-GO)	ORG/MGMNT/ PLANNING (GO/NO-GO)	MANAGEMENT (GO/NO-GO)
	OTHER LIFE CYCLE COSTS (10%)	TEST AND EVAL (10%)			
		COMMON AVIONICS BASE-LINE IMPL (GO/NO-GO)			
		OPERATIONAL SUITABILITY (GO/NO-GO)			

Example

HOW RAM BENEFITS THE FIELD

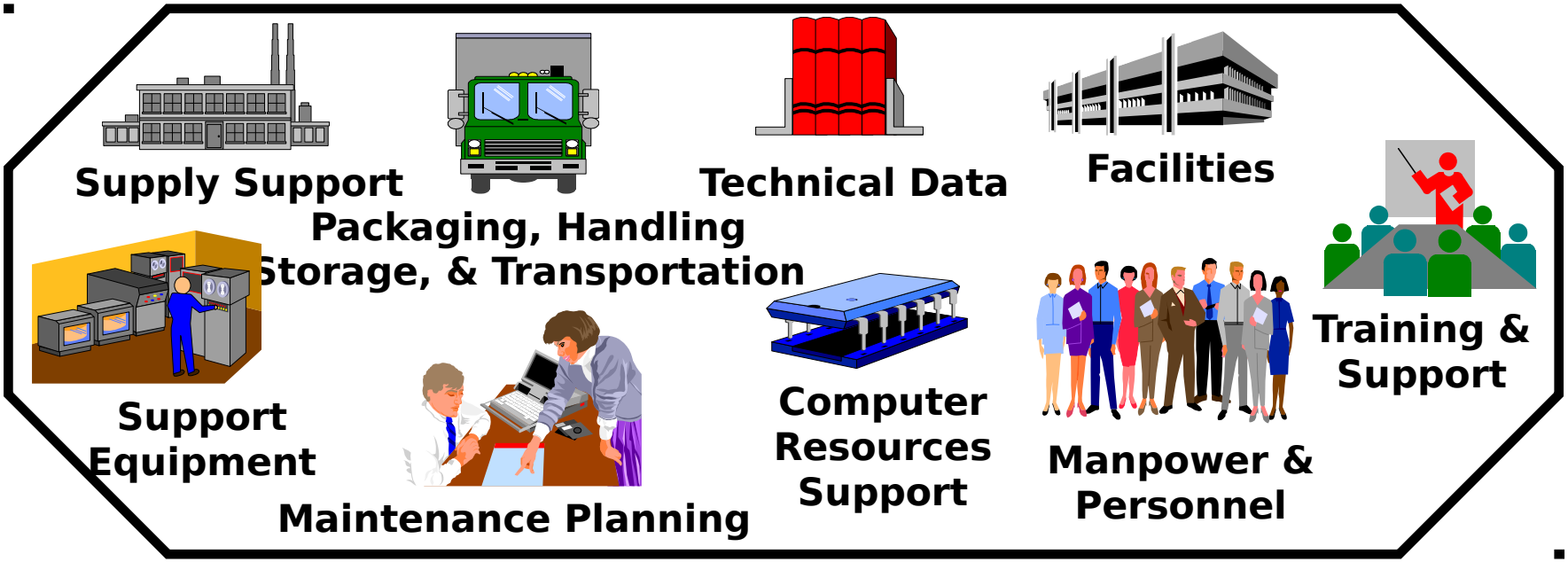
RAM characteristics are not important in themselves;
Achieving the objectives listed below is what is important

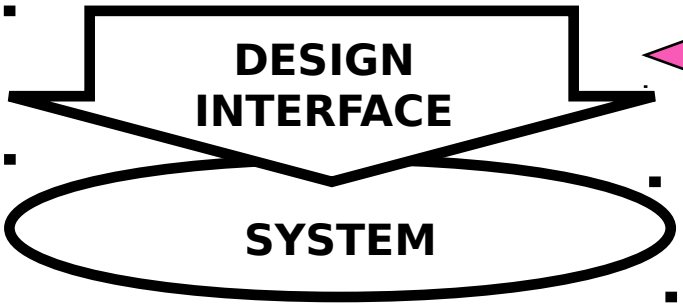
- Increased combat capability
  - Improve operational readiness / availability
  - Better system utilization
  - Higher probability of mission success
- Reduced Life Cycle Costs
  - Less maintenance manning
  - Decreased logistics support footprint



RAM characteristics are important to th
they influence the ability to achieve the above goals.

BEST PRACTICE: SUPPORT ELEMENTS

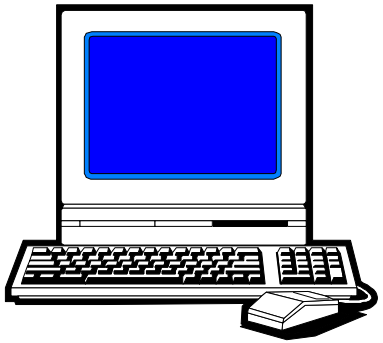




Reliability
Maintainabili
HSI

MMoSSTT
ComFa
PaD

RAM WEB SITES



- **Reliability Analysis Center (RAC)** - a DoD information analysis center. Serves as a Gov't and industry focal point for efforts to improve the reliability, maintainability and quality of manufactured components and systems.

  http://rac.iitri.org/RAC

- **Gov't Industry Data Exchange Program (GIDEP)**

  Contains R&M data interchange.

  http://www.GIDEP.CORONA.NAVY.MIL

Additional Slides

Provided for reference only

RAM ACTIVITIES FOR NEW DEVELOPMENT vs COMMERCIAL/NDI

RAM Activity	New Development	Commercial/NDI
RAM Analysis/ Requirements	• User Needs • Technology in use	• Verify Manufacturer's claims
RAM Design	• Perform FMECA, Derating, etc. • Manufacturing retains inherent R&M characteristics	• Limited to integration and modification • Mods based on environment application
RAM Test	• Extensive Development tests	• Verify Manufacturer's claims
RAM Contracting	• Source Selection • Determine Warranties • Incentives	• Market Survey • Accept Manufacturer's Warranties • Contractor Test Data